MANAGING KNOWLEDGE TO PROMOTE SUSTAINABILITY FOR INFRASTRUCTURE DEVELOPMENT

Jay YANG[1]
Mei YUAN[2]


Keywords: *sustainability, infrastructure, knowledge management, project management*

Abstract

On the back of years of strong economic development and the boom of resource export more recently, new construction and redevelopment of infrastructure has become a critical issue in Australia. As the construction processes involved in these projects have significant impacts on the environment, people's lifestyle and local economy, sustainability issues have been high on the discussion agenda for many stakeholders. However past research indicated that problems in pursuing infrastructure sustainability often lies with what should be done, who should do them and how mutual benefits can be delivered to those involved. These problems are compounded by the fact that very often there are no common understandings between the stakeholders. Other sectors of the industry, such as commercial office buildings, have been more successful in raising the bar of sustainability through rating tools, innovations, and policies, with up-to-date knowledge captured and encapsulated into these measures. To rectify the problems in the infrastructure sector, it is both feasible and timely to develop and expand the body of sustainability knowledge on infrastructure development and investigate ways of communicating with and managing it within the sector.

Despite being a relatively new and emerging concept, knowledge management (KM) has been used to develop mechanisms and tools for managing information and knowledge in a diverse range of contexts in many sectors of industry and business. An ongoing research project, undertaken by Queensland University of Technology in Australia, is introduced in this paper. The project is aimed at establishing a specific KM approach to facilitate better decision making during sustainable infrastructure development. It highlights the unique characteristics of the infrastructure industry as well as the nature of sustainability knowledge. Existing KM mechanisms and tools are discussed as well as adaptation plans to customize them to the context of infrastructure and sustainability knowledge. A platform of best practice for managing sustainability knowledge among all stakeholders will be developed through this project to promote sustainability uptake during project development lifecycles.

1. Introduction

Throughout history, civilization has depended on the ability and will of communities, cities and nations to finance, build, operate and maintain infrastructures (e.g., road and water supply facility), the physical backbone of societies. As the result of the strong growth of prosperity, population, and global competition, the demand for infrastructure is creating bottlenecks for economic development in many parts of the world and has become a global phenomenon (Asian Development Bank, 2007).

In Australia, especially in Queensland and Western Australia, unprecedented population and economic growth is driving the need for new infrastructures. Queensland is the fastest-growing state in Australia, welcoming up to 100,000 new residents annually - with 66% of them relocating to the state's south-east corner. On the other hand, the world's growing demand for Australian resources – such coal, iron ore, zinc and copper - is generating a need to upgrade port facilities, rail links, roads and energy networks to capitalize on emerging opportunities. Thus, the Queensland Government is planning and delivering the most ambitious infrastructure program since Federation, committing more than $100 billion in the next 18 years in the plan to secure Queensland's prosperity and lifestyle (Queensland Government, 2008).

The output of the ambitious agenda has a major impact on the state's ability to maintain a sustainable economy overall however has significant disturbance to the natural environment and local community. Infrastructures typically occupy vast land, span over a long duration and consume significant amount of resources, thus drawing close relevant all facets of sustainability issues. With World heritage listed natural environment and resources, both the industries and Government accepted that when developing and

[1] Faculty of Built Environment and Engineering, Queensland University of Technology, Australia, j.yang@qut.edu.au
[2] Faculty of Built Environment and Engineering, Queensland University of Technology, Australia, mei.yuan@student.qut.edu.au

upgrading infrastructure, they should take actions to achieve the overarching targets within each of the main areas of the sustainability agenda.

However, in the construction industry, sustainability considerations and applications are still at the infant stage. The gap between advancement of research and real life applications in actual projects is still significant. The lag can be caused by many reasons and obstructions. In this paper, the authors focus on the insufficient gathering and application of sustainability knowledge and the low efficiency that the industry manage such knowledge, in order to identify ways to rectify the problems through knowledge management mechanisms and tools.

2. Infrastructure Industry and Sustainable Development

For infrastructure development, the scope of sustainability knowledge is very broad. Despite being an evolving concept and ideology, the importance of sustainability is generally well accepted and echoed by various industries, including the construction industry. Sustainable construction can be seen as a construction process which incorporates the basic themes of sustainable development, addressing environmental responsibility, social awareness, and economic profitability objectives. Theoretically, all related knowledge oriented from sustainable development, sustainable construction, green building et al can be borrowed to infrastructure sector, making the scope of the body of knowledge very broad.

At the same time, sustainability considerations and applications in infrastructure sector are still scarce as very little sustainability knowledge is right available and specific for infrastructure development. Within the construction industry, the commercial building sector is more successful in adopting sustainability principles, both in theory and practice, through rating tools, innovations and policies with up-to-date knowledge captured and encapsulated in these measures. Infrastructure sector lagged far behind. The term “sustainable infrastructure” was first used by Canada Government to describe the goal of their InfraGuide project operated from 2001 to 2007 (Federation of Canadian Municipalities, 2007). Reviewing of literatures indicate that in academia, infrastructure attracts little attention. It was not until very recent years that there are some research targeting at assessment indicators, tools et al that specific for sustainable infrastructures.

The authors attempt to categorize existing sustainability knowledge for infrastructure development into 4 groups as shown in the following table: assessment tools, government guidelines, organization procedures/methods and project experiences. Most of the knowledge needs further development to be adopted in real infrastructure development projects.

Table 1 Existing Sustainable Infrastructure Knowledge

	Assessment Tools (BREEAM, LEED, GREENSTAR, etc.)	Government Guidelines/Polices (InfraGuide, Agenda21, PRESCO, etc.)	Organization Procedures/ methods	Project experiences
Location Type Character	External resources Explicit • Mainly for building assessment and need further development.	External resources Explicit • Vague and general.	organizations Explicit/tacit • Hard to change; • Prevented to share amongst organizations	Individuals Explicit/tacit • mostly reside in people minds; • Hard to track, record and widely share.

Not only the lack of body of sustainability knowledge itself, but the nature of the construction industry – where knowledge generate, flow and apply – is also causing setbacks for sustainability consideration and applications. Sustainability issue is broad and complex thus needs innovative solution. However the construction industry is always seen as a stubborn, risk averse and highly traditional industry which is laggard at adopting innovation (Taylor and Levitt, 2005). Construction processes, especially for infrastructure development, are always demanding and stressful, making professionals unwilling to learn or develop innovative solutions to carry out tasks.

The construction industry is also a complex and structured industry which has considerable fragmentation and low communicating efficiency among stakeholders (Maqsood, 2006). Typically the duration of the whole life cycle of infrastructure development is very long and comprises many stages. Many important stakeholders come from wide ranged disciplines of private and public sectors. They often represent contrasting views and professional foci when involved in the decision making and project implementation processes. Within the industry, problems often lie with what should be done, who should do them and how mutual benefits can be delivered to those involved. These issues are compounded by the fact that very often there are no common understandings between the stakeholders. Moreover, the fragmentation caused by different participants in a project always tends to lead to misunderstandings and misconceptions.

Thus, to justify the problems and promote sustainability in the industry, it is both timely and feasible to:

- Expand the body of sustainability knowledge specific for infrastructure development;
- Search better ways to trigger knowledge creation, sharing and application in order to facilitate the industry with dense and up-to-date knowledge and expertise to promote integrated decision making thus to promote sustainability.

Although being a relatively new and emerging discipline, knowledge management (KM) has been proven as a valuable tool for construction innovation and should be a feasible solution to address these emerging needs.

3. Knowledge Management and its Applications in the Construction Industry

3.1 The KM Concepts and Evolution

The quest for obtaining knowledge and effectively utilizing it is not new. However it was not until late 1980's that individuals and organizations began to appreciate the increasing important role of knowledge in the emerging competitive environment (Wiig, 1997). And since then the phase "knowledge management (KM)" entered popular usage, evidenced by the extensive KM articles, books and conferences. All of these are triggered by the invention and dissemination of computer and World-Wide-Web and linked to the profound revolution based on information and knowledge that we are going through (Dalkir, 2005).

KM is now a broad and expanding topic contributed by diverse range of disciplines with a multifold mix of strategies, tools, and techniques. Although no well accepted definition regarding to "what is KM" can be obtained in current literature due to its multi-discipline nature, there is a consistent theme found in all available definitions: "KM can provide access to information at the time people need it to make the best decisions possible for mission success and efficiency by providing a framework that builds on past experiences and creates new mechanisms for exchanging and creating knowledge (Teece, 2000)".

Another fundamental question in this discipline is around what is knowledge. Researchers often avoid epistemological debate on the definition of knowledge by comparing and classification. Alavi and Leidner (2001) summarized the existing taxonomies of knowledge, such as tacit knowledge vs. explicit knowledge, individual knowledge vs. social knowledge, declarative knowledge (know-about), procedural knowledge (know-how), causal knowledge (know-why), conditional knowledge (know-when), relational knowledge (know-with), et al. Among these taxonomies, the most commonly received one is that there are two fundamental dimensions of knowledge: tacit and explicit.

Drawing on the work of Polanyi (1962, 1967), tacit knowledge refers to knowledge that is embedded in individual experience, such as perspective and inferential knowledge. Tacit knowledge includes insights, hunches, intuitions and skills that are highly personal and hard to formalize, making them difficult to communicate or share with others. Explicit knowledge is knowledge that has been articulated in formal language and which can be easily transmitted amongst individuals. It can be expressed in scientific formulae, codified procedures or a variety of other forms.

Since the inception of the KM in last decades, organizations have undertaken various KM related initiatives to survive market competition and development of knowledge economy. As they acknowledged that both explicit and tacit knowledge are important for the organization and both must be recognized as providing value to the organization, the goal of the initiatives, then, is to leverage knowledge and reduce the size of the organizational knowledge gaps.

KM Cycle is widely used as a KM approach. Major presentations encompass the capture, creation, codification, sharing, accessing, application, and reuse of knowledge within and between organizations. The identifications of KM cycle of KM stages set a foundation for KM implications which focus on knowledge processes and enablers. The adopters of the new discipline have followed different approaches to trigger and facilitate knowledge flow within the cycle with varying emphasis on technological, culture, organizational and managerial issues. Usually, two main perspectives of KM are usually employed, objective and subjective (Mentzas, 2004).

The objective approach implies that knowledge is a thing that can be located and manipulated as an independent object. This approach mainly focuses on products and artifacts containing and representing knowledge, this usually means managing documents, their creation, storage, and reuse in computer-based corporate memories, such as best practice database and lessons-learned archives; case-bases, which preserve older business-case experience; knowledge taxonomies and formal knowledge structure, etc. This approach is also referred to as 'content-centered', 'codification', 'product' or a 'people-to-document' approach.

The 'subject' approach puts emphasis on ways to promote, motivate, encourage, nurture or guide the process of knowing, and abolishes the idea of trying to capture and distribute knowledge. This view mainly understands KM as a social communication process, which can be improved by collaboration and cooperation support tools. In this approach, knowledge is closely tied to the person who developed it and is shared mainly through person-to-person contacts. The main purpose of Information and Communication Technology (ICT) in this case is to help people communicate knowledge, not store it. This approach has also been referred to as 'collaboration', 'personalization', 'process' or a 'people-to-people' approach.

To select or adopt the appropriate KM approach, it is suggested that the nature of the industry, organization characteristics, the peculiarity of its products and services and organizational culture should be considered

(Hansen et al, 1999). However, there are more calls for an integrated approach that reflects both the object and the subject perspectives. Since each perspective identifies important elements for successfully implementing KM initiatives, such as knowledge repositories and retrieval technology, knowledge codification et al from the 'object' approach and emphasis on organizational culture, net-working, team developing et al from the 'subject' approach, it is a real need for the balanced fusion of two perspectives and treat and carry into KM in a holistic and evolutive way (Weber et al, 2002; Mentzas, 2004; Rubenstein-Montano et al, 2001).

3.2 KM in Construction Industry

In construction industry, KM has been "imported" as a useful tool for some years. Practical means of implementing KM in the construction industry through various mechanisms and tools are demonstrated through literatures. Studies ranging from the implementation of decision support systems, external provision of knowledge management services, internal exertion of knowledge management, learning histories, innovation, and so forth provide enriching practical experiences in KM implementation.

However, it is obvious that despite these efforts which separately deal with just one or some aspects of KM, such as exploring culture as important enabler of KM application and innovation development, or addressing the issues of capturing, storing, and transferring knowledge in construction industry, there is no research outlines KM as a solution in a holistic and highbird view.

Furthermore, there is still very limited KM approaches brought forward with the aim to bring an awareness of sustainability issues in construction processes, and even less on how to ensure that knowledge is readily available to individuals, project teams, and companies at the project level.

Moreover, in relating knowledge management to the construction sector, managing this knowledge is of great importance, especially to large scale infrastructure development due to the unique characteristics of each project, i.e. multi-disciplinary teams, dynamic participation of team members, heavy reliance on previous experience, the one-off nature of the projects, long period of project life cycle, tight schedules, limited budget, etc. However, up to now, no such research of specific KM solutions in the context of infrastructure projects has been conducted.

To address these calls, the authors consider KM framework as a possible solution to trigger knowledge creation, sharing and application and provide a platform for stakeholders' knowledge communication to facilitate better understanding and decision making, thus promoting sustainability agenda in the infrastructure sector.

4. Knowledge Management Framework

4.1 Previous Frameworks and Application

As many researchers and practitioners have found, successful KM is a balancing act. While experience has shown that, other than the widely recognized technology issues, socio-cultural issues are often the most difficult to tackle, it is equally important to keep in mind the "bigger picture" – the wider economic, technological and structural issues facing the organization as it strives to innovate faster and within which any corporate KM initiative inevitably takes place. Hence the aim of developing a framework, as identified by the European Committee for Standardization (2004), is to link the various components of knowledge management (people, process, technology) to each other and provide a schematic picture of how these aspects depend on and interact with each other and how it helps to position KM initiatives.

Roberson (2002) argues that there are many benefits can be gained from the development of KM framework which can provide consistent language, outline a process, provide a checklist, offer a source of ideas and address non-technical aspects.

With the explosive growth of interest in KM, many different KM frameworks have been produced in order to help the real world's organizations to implement KM.

Rubenstein-Montano et al (2001) reviewed 26 existing KM frameworks and classified them into two types: prescriptive and descriptive. Prescriptive frameworks provide direction on the types of knowledge management procedures without providing specific details of how those procedures can/should be accomplished while, in contrast, descriptive frameworks characterize or describe KM. These researchers found that the majority of frameworks they reviewed are prescriptive and thus tend to be task-oriented. They emphasize placing KM in a larger context of systems thinking so that influencing factors on its success or failure can better be recognized and understood. They also provide suggestions on what a general framework should include: (1) the framework should be both prescriptive and descriptive, (2) knowledge management activities must be consistent with systems thinking, which means: (2a) the organizational strategies and goals must be linked to KM, (2b) planning should occur before knowledge management activities are undertaken, (2c) culture aspects of an organization must be recognized and KM must occur in a manner compatible with the culture of the organization, and (2d) knowledge management is an evolutionary, iterative process directed by feedback loops and learning.

A KM framework delivered by European Committee for Standardization (CEN) (2004) is one of the good examples of existing frameworks which sets the overall context for KM at both the organizational and personal level to promote a common European understanding of KM, show the value of the emerging KM approach and help organizations towards its successful implementation. This KM framework considers three layers as most important for KM: the core value-adding processes, the five core knowledge activities and the

KM enablers (as shown in figure 1). It emphasizes that business focus should be in the centre of any KM initiative and represents the value-adding processes of an organization, which may typically include strategy development, product/service innovation and development, manufacturing and service delivery, sales and customer support. Five core knowledge activities (which is called KM cycle typically in other literatures) in the second layer have been identified as: identify, create, store, share and use. The enablers are identified in two categories: personal knowledge capabilities, which include ambition, skills, behavior, experience, tools and time management, etc., while organizational knowledge capabilities include the mission, vision and strategy, the design of processes and organizational structures, measurement, understanding of the culture, the use of technology and infrastructure, etc. This hierarchical framework distinguishes the core aim of KM, the core activities and the KM environment clearly; however it is so general and need to be further developed for specific use in any industry or organizations.

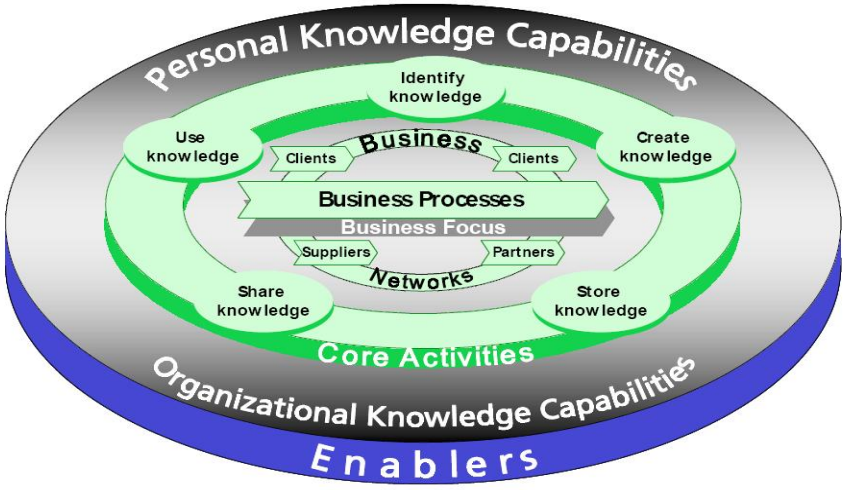

Figure 1 Knowledge Management Framework: A European Perspective (European Committee for Standardization, 2004)

Other than these pure KM frameworks, specific KM frameworks are developed to be integrated with some specific management issues, such as business process management, leveraging knowledge innovation and organization innovation capacity audit, leveraging knowledge assets, et al. Examples can be seen in (Biloslavo, 2005; Choi, et al, 2004; Maier and Remus, 2001; Mentzas, 2004; Sung, 2006; Wild, et al, 2002).

Moreover, there are some KM frameworks tailored for some specific industries. Jafari et al (2007) provide us with an example through the investigation of the role of KM in Iran aerospace industries and the development of a KM framework specially designed for aerospace industries towards a knowledge-based organization.

4.2 A Knowledge Management Framework for Sustainable Infrastructure Development

In the infrastructure sector, as indicated previously, there is a need for both academia and industry to build and expand the body of sustainability knowledge specific for infrastructure development as well as searching for better ways to trigger knowledge creation, sharing and application in order to promote sustainable agenda. In response to this, a research project is being conducted in the Queensland University of Technology (QUT), aiming at establishing a KM framework specific for infrastructure industry to better manage sustainability knowledge. Considering the relevance of industry sectors and applications, the above mentioned KM frameworks are considered adaptable and have set a good foundation for this research.

With reference to discussions in previous sections of this paper, the following research questions are being probed in this research:

- What are the unique natures of sustainability knowledge that should be considered during the development of infrastructure projects?
- What are the key elements in KM frameworks when managing such sustainability knowledge particularly suited in the context of infrastructure development?
- How can the construction industries efficiently use the framework to apply KM?

To avoid ‘reinventing the wheel’ and to make the most out of previous efforts, this research intends to adopt an existing KM framework as the prototype for further adaptation and development in order to produce a new framework accustomed to infrastructure context. Such a prototype will then be provided with new details and expanded levels of activities through information obtained by questionnaire survey and case studies. The development process and plan is shown in Figure 2.

The literature studies and preliminary research on organizational operations and government policies on infrastructure has presented an initial set of characteristics of sustainable knowledge deemed important and unique to infrastructure settings. The questionnaire surveys, being conducted right now, will produce information from domain infrastructure construction organizations on what are the appropriate processes/approaches/methods for the construction organizations to implement sustainability principles and knowledge. The questionnaire covered over 90 issues/questions in several categories such as sustainability foci, sustainability value adding processes, appropriate KM activities, and sustainability KM enablers. All the elements in the prototype will be tested through the survey, seeking professional and industrial involvement. Results of this stage of research will help generate a preliminary KM framework.

The preliminary framework will then be expanded and verified through select cases studies during the final stage of research development. It will include formulation of contextual and visual representation of the final framework. The development of a set of application guidelines, in the form of procedure-driven "how to apply" operational manual, will ensure that the industries and practitioners first-hand reference to using KM principles to improve their game of sustainable infrastructure delivery.

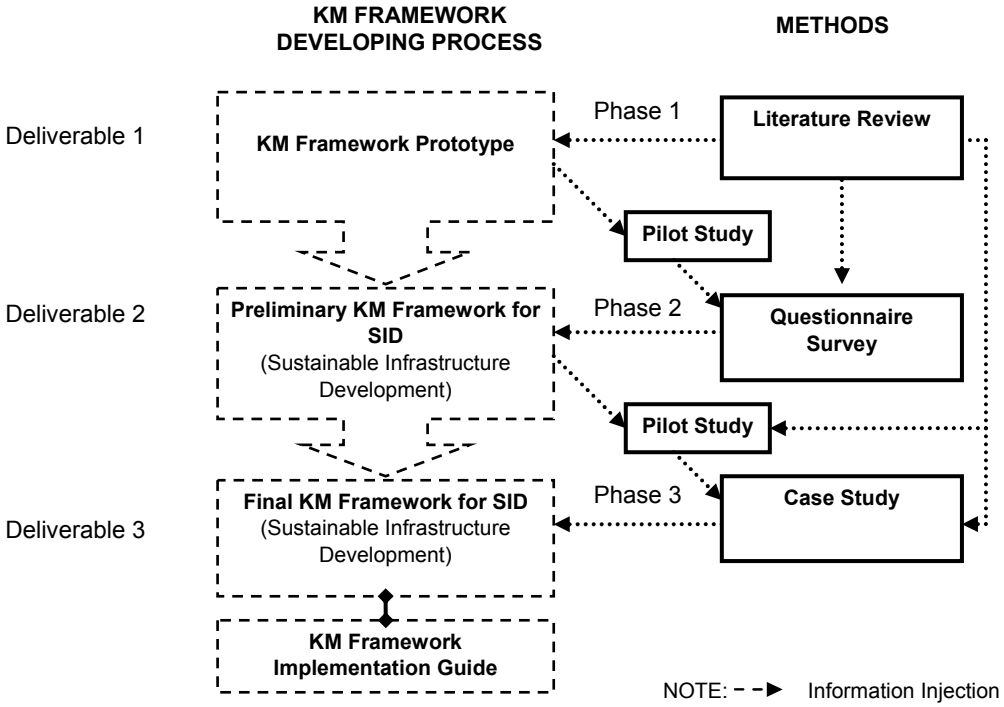

Figure 2 Developing Process of the KM Framework for Sustainable Infrastructure Development

5. Conclusion

It has been identified that sustainability issues have been high on the discussion agenda for infrastructure development. However sustainability considerations and applications are still at the infant stage especially at project levels.

This paper suggests that both scarcity of sustainability knowledge on infrastructure and the nature of the industry itself are creating obstructions for the promotion of sustainability. Thus it is feasible and timely to develop and expand the body of sustainability knowledge on infrastructure development and investigate ways of communicating with and managing it within the sector. KM has been considered as a possible approach which can provide a platform for all the stakeholders and the community to share ideas and experiences, to inspire new researches and practices, thus to promote sustainability.

On the basis of evaluation of past KM mechanisms and approaches, specific KM frameworks are considered capable of providing an integrated KM solution while catering for the 'big picture', outlining a process, offering source of ideas and addressing non-technical aspects. An ongoing QUT research aimed at establishing a KM framework specific for sustainable infrastructure development was introduced. Prototype of the framework has been identified for further development. Surveys are being conducted to demonstrate the appropriate levels of knowledge, identify issues that impact on knowledge take-up and transfer, and provide integration between key stages of decision making during the development of infrastructure projects. With keen participation of industry partners, it is hoped that such an approach will ultimately promote the sustainability agenda among major decision makers of each stakeholder involved in large and complex projects of infrastructure being developed in Australia.

References

Alavi, M. and Leidner, D. E. 2001, Review: knowledge management and knowledge management systems: conceptual foundation and research issues. *MIS Quarterly, 25*(1), pp. 107-136.

Asian Development Bank. 2007, *Asian development outlook 2007 - Growth admit change*: Asian Development Bank.

Biloslavo, R. 2005, Use of the knowledge management framework as a tool for innovation capability audit. International Journal of Innovation and Learning, 2(4), pp. 402-424.

Choi, I. et al. 2004, A framework for the integration of knowledge management and business process management. *International Journal of Innovation and Learning, 1*(4), pp. 399-408.

Dalkir, K. 2005, *Knowledge Management in Theory and Practice*. Oxford: Elsevier Inc.

European Committee for Standardization. 2004, *European Guide to good Practice in Knowledge Management - Part 1: Knowledge Management Framework*. Brussels.

Federation of Canadian Municipalities. 2007, InfraGuide: The National Guide to Sustainable Infrastructure. (Retrieved May 2008, from http://www.sustainablecommunities.fcm.ca/Infraguide/)

Hansen, M. T. et al. 1999, What's your strategy for managing knowledge? *Harvard Business Review, 77*(3), pp. 107-116.

Jafari, M. et al. 2007, Establishing an integrated KM system in Iran Aerospace Industries Organization. *Journal of Knowledge Management, 11*(1), pp. 127-142,.

Maier, R., and Remus, U. 2001, *Towards a framework for Knowledge Management strategies: process orientation as strategic starting point.* Paper presented at the 34th Hawaii International Conference on System Sciences, Hawaii.

Maqsood, T. 2006, *The Role of Knowledge Management in Supporting Innovation and Learning in Construction* RMIT University, Melbourne.

Mentzas, G. 2004, A strategic management framework for leveraging knowledge assets. *International Journal of Innovation and Learning, 1*(2), pp. 115-142.

Polanyi, M. 1962, *"Personal Knowledge" In Meaning*. Chicago: University of Chicago Press.

Polanyi, M. 1967, *The Tacit Dimension*. London: Routledge and Keoan Paul.

Queensland Government. 2008, Key infrastructure. (Retrieved November 2008, from http://www.dip.qld.gov.au/key-infrastructure/index.php)

Robertson, J. 2002, Benefits of a knowledge management framework [Electronic Version]. (Retrieved May 2008, from www.steptwo.com.au)

Rubenstein-Montano, B. et al. 2001, A system thinking framework for knowledge management. *Decision Support System, 31*, pp. 5-16.

Sung, A. G. L. 2006, A strategic management framework for leveraging knowledge innovation. *International Journal of the Computer, the Internet and Management, 14*(3), pp. 32-49.

Taylor, J. E., and Levitt, R. E. 2005, Inter-organizational knowledge flow and innovation diffusion in project-based industries. In Proceedings of the 38th Annual Hawaii International Conference on System Sciences, 2005. Hawaii, USA.

Teece, D. J. 2000, Strategies for managing knowledge assets: the role of firm structure and industrial context. *Long Range Planning, 33*(1), pp. 35-54.

Weber, F. et al. 2002, Standardisation in Knowledge Management: towards a common KM framework in Europe. Paper presented at the UNICOM Seminar "Towards Common Approaches and Standards in KM", London.

Wiig, K. M. 1997, Knowledge management: an introduction and perspective. *The Journal of Knowledge Management, 1*, pp. 6-14.